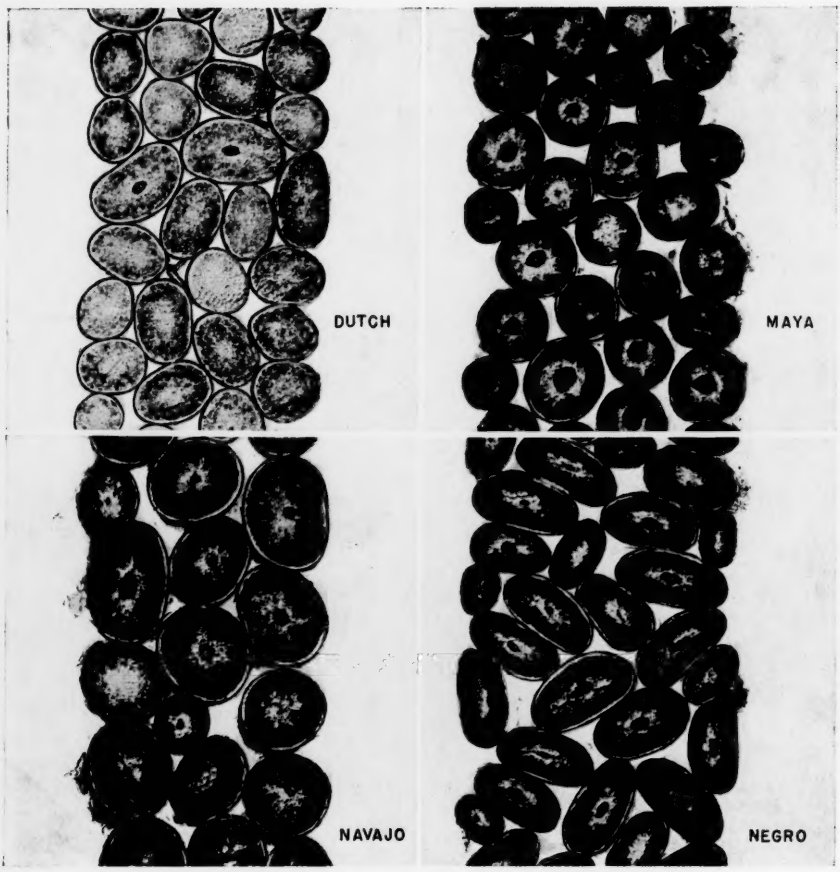
The Journal of HEREDITY



ARE HAIR-CONTOURS A RACIAL CHARACTER?
(SEE PAGE 475)

Hairless and Rhino Mice

Fuzz-Lint Relationships in Cotton

New Crossroads in Cancer Research

Induced Tetraploids in a Dioecious Plant

VOLUME 31 NOVEMBER, 1940 NUMBER 11

The American Genetic Association

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The

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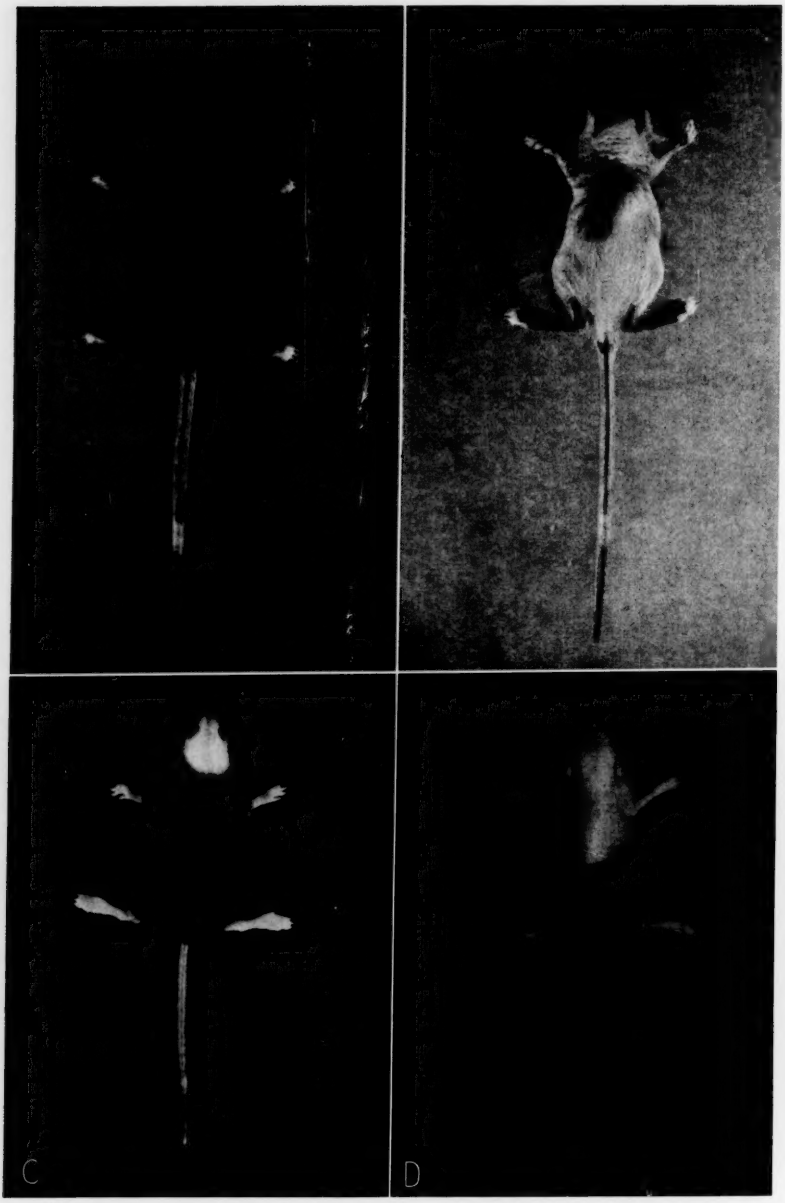


DIFFERENT SHEDDING PATTERNS OF RHINO AND HAIRLESS MICE

Frontispiece

The Rhino mouse (*A—B*) begins to lose its hair at 14 days. By 24 days (*A*) the hair is thin all over the body. Four days later (*B*) the same mouse has lost much of its hair except on the extremities. The hairless mouse (*C—D*) loses its juvenile coat in a different pattern. At 18 days (*C*) a black hairless mouse has shed the hair on the extremities and head. Three days later (*D*) half the body is bare. These differences in the manner in which the hair is shed are characteristic of these two distinct types of hairlessness, which are alleles of the same gene.

"RHINO," AN ALLELE OF HAIRLESS IN THE HOUSE MOUSE

ALMA HOWARD*

Department of Genetics, McGill University, Montreal

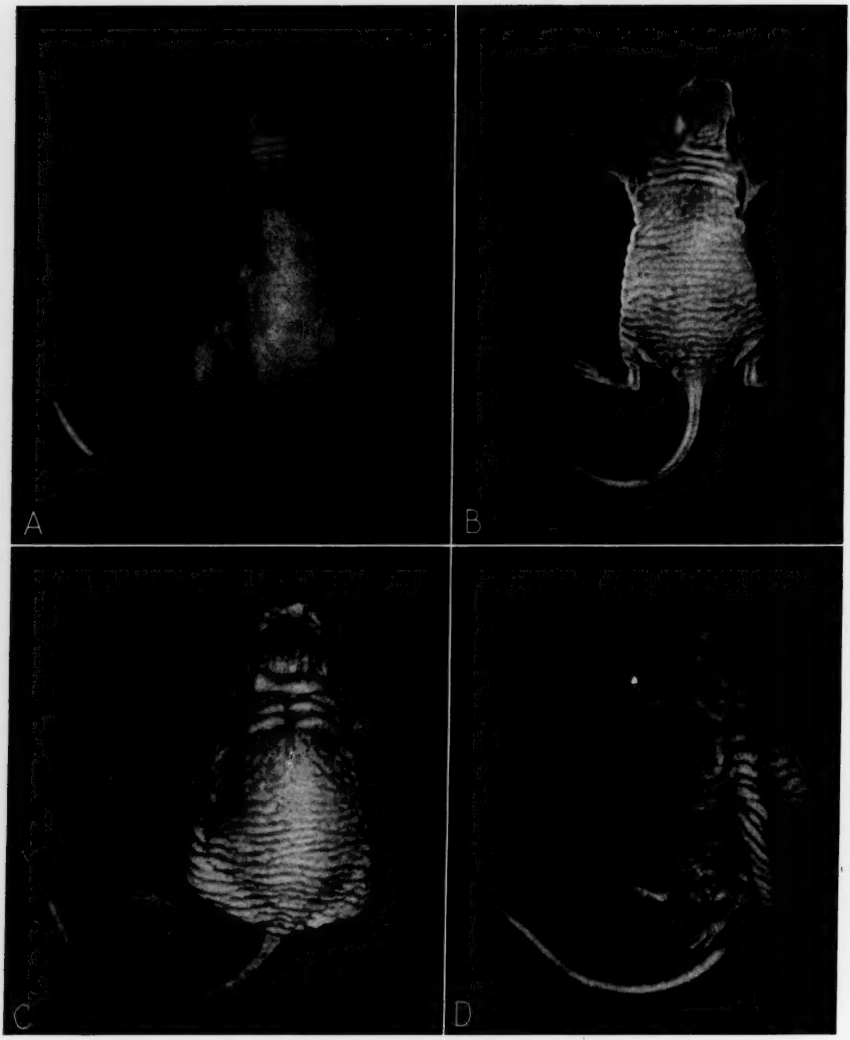
IN 1856 Gaskoin[6] described a family of mice found near Maidenhead, England, which in the neighborhood had been termed "rhinoceros mice" because of their hairless and very wrinkled or "corrugated" skin. Gaskoin considered them a variety of the common house mouse and gave them the name "nudoplicatus." This was not the first appearance of mice of this type, for Gaskoin refers to a preserved specimen presented to the museum of the College of Surgeons, London, in 1820, which closely resembled his animals. Nor was it the last. Allen's[1] description of a mouse caught in Boston about 1904 is strikingly like that of Gaskoin, and Campbell[2] in 1907 published an account and photographs of mice obtained from a dealer in London which were of a similar type. The present report describes the genetic behavior of a recent mutant whose appearance is so similar to these earlier ones that it can justifiably be considered a recurrence of the same mutation, and has for this reason been given the name "rhino."

The new mutation appeared in June, 1939, in two litters mates of the fifth generation of brother-to-sister mating in a stock derived from a cross between two highly inbred lines. The abnormality is inherited as a simple recessive. The homozygotes are normal in appearance up to 13 or 14 days of age, when the hair just above the eyes begins to fall out. At 15 days the coat is thin all over, but especially on the head, shoulders, belly and upper legs. This thinning progresses until at three to four weeks only the feet, tail and ears are haired, although a few scattered hairs may remain on the back until about five weeks of age. The coat persists longest on the hind feet, where it may remain as late as the seventh week. Loss of hair proceeds in general in an anterior-posterior direction. This is particularly well marked on the tail, where the hairs fall out in a wave from base to tip. On the dorsum, however, thin hair may remain in the shoulder region for some days after it has disappeared from the tail region. The vibrissae remain throughout life, but as the mouse grows older become shorter, less numerous, and bent.

At three weeks of age, or soon afterwards, homozygous rhinos begin to show a wrinkling of the skin which follows a characteristic pattern, with transverse ridges on the nose, back and belly, longitudinal ridges on the forehead, and a lateral fold on the abdomen running from the foreleg to the hind leg. The wrinkles appear first over the head and neck. A gradual thickening of the skin intensifies these ridges until at six months or earlier an extreme "rhinoceros" appearance is reached. The nose ridge becomes so heavy that vision is seriously restricted if not totally obliterated. The lateral abdominal folds develop enormously so that they drag on the floor of the cage: the abdominal folds may be so deep that the hind feet can reach the floor only when fully extended, with consequent hampering of the animal's movements. As the skin thickens and becomes folded, it shows a number of small lumps beneath its surface. These lumps increase in size and number with age, and are particularly noticeable on the tail and ears.

At about five weeks of age an overgrowth of the claws of all four feet can be observed, and this also increases with age. The outer two claws of each hind foot tend to grow into a spiral shape, while the center ones, and all the claws of the forefeet, curve more or less ventrally. At 8-10 months the claws are

*Finney-Howell Research Fellow.



ADULT HAIRLESS AND RHINO MICE

Figure 1

At six months (*A*) this female hairless mouse has a smooth skin. The wrinkling of the neck is characteristic but this is never extensive enough to cause hairless to be confused with the rhino type (*B—D*). At three and a half months (*B*) the rhinos show a marked wrinkling of the skin. This grows progressively greater and at ten months (*C—D*) a typical rhino male has this weird appearance. The claws are also excessively overgrown, much more so than in the hairless mice.

sometimes as much as a centimeter in length. Their ventral curvature forces the animal to walk on the hind part of the foot and further impedes movement. The claws are seldom found to be broken. The hypertrophy, especially on the forefeet, tends to be greater in males than in females.

The teeth of rhino animals are apparently functionally normal, although young rhinos show a tendency to suckle rather longer than the normal period when the only alternative food is in the form of hard pellets.

Rhinos of both sexes are fertile, but females are unable to produce enough milk to raise their young, which must be given to a foster-mother if they are to survive. Apart from this, rhinos are good breeders, either *inter se* or with normally haired animals.

Rhino a Recessive

In outcrosses with normal stock the rhino gene behaves as a simple recessive, heterozygotes being completely normal and the F_2 giving a 3:1 ratio of normal and rhino (45:17). In a cross with a mouse homozygous for hairless (*hr*),* all the F_1 and F_2 animals are hairless. Since hairless is also a simple recessive,[3] this lack of normal animals indicates that rhino is an allelele of hairless, and for this reason the gene has been given the symbol hr_{rh}.

Several differences exist between rhino (hr_{rh} hr_{rh}) and hairless (*hr hr*) animals. The most striking is in the adult skin. Hairless mice remain almost or completely smooth-skinned throughout life. Thin animals of six weeks of age may show a certain amount of wrinkling, but this does not follow the characteristic rhino pattern, and disappears when the mice fill out. In adults the cutis thickens[4] and older mice may have two or three folds at the back of the neck, but never to an extent comparable with rhinos. A second difference is in the manner of loss of the first coat. At 13 or 14 days hairless homozygotes lose the hair above the eyes and on all four feet, and during the next week become completely bare, hairless areas expanding from these points caudad. The initial loss of hair on the feet gives a characteristic appearance never seen in rhinos, whose feet remain haired until relatively late. In a segregating population it is possible on this basis accurately to predict at 14 days the adult skin character.

Young rhino mice during depilation show a gradual thinning of the coat over the head and back, after which bare areas appear. Hairless animals, on the other hand, lose their hair progressively from head to tail, and there is no intermediate thin condition, hairless and haired areas being sharply demarcated at all times.

While rhino mice are thus distinctly different from hairless, they are on the other hand strikingly similar to the "rhinoceros" or "nudo-plicatus" type described in the earlier literature. Campbell's[2] photograph (see his Figures 4 and 5) of one of his mutants shows a thin coat very much like that seen in rhino animals at about three weeks (cf. Frontispiece here). Campbell illustrates also (his Figures 2 and 3) an adult with a wrinkled skin closely resembling the adult illustrated here, and remarks that blindness was common. If the recent mutation is, as seems probable, a recurrence of Campbell's, it explains why the Crew hairless mutants differ from Campbell's in having a smooth skin, although Campbell's gene, like hairless, behaved as though linked with piebald.[7]

Fertility Not Affected

It is doubtful whether any difference exists in the fertility of rhino and hairless mice. Although several authors[3,5,7] have reported difficulty in breeding hairless animals, particularly females, both sexes have bred fairly well in our colony and cannot be said to be less fertile than rhino mice under the same conditions. Hairless females, like rhino, have reduced mammary tissue and are unable to raise their young. Females of the cross rhino × hairless, however, have on several occasions raised small litters.

*I am indebted to Dr. C. C. Little and to Dr. George Snell of the Roscoe B. Jackson Laboratory for hairless mice from their colony.

F_1 animals resemble hairless mice both in the manner of hair loss and in the smooth skin of the adults. The F_2 population falls into two classes, the hairless type being three times as numerous as the rhino (32:11). It has not been possible to subdivide the hairless class phenotypically. The hairless allele is thus dominant to the rhino allele.

The histological appearance of the skin of hairless and naked mice and their hybrids has been described by David.[5] It is hoped shortly to undertake a study of the dermal histology of rhino mice and their hybrids with hairless and naked.

Summary

1. A mutant gene, "rhino," which appeared in a laboratory stock of the house mouse, causes, in the homozygous condition, a progressive thinning and final permanent loss of the hair at 2-4 weeks of age, hypertrophy and curvature of the claws, and a marked wrinkling and thickening of the skin at three months and later. Both sexes are fertile, but females have a reduced amount of mammary tissue and are incapable of supplying adequate milk to their young.

2. Rhino is an allele of hairless (*hr*) and is recessive both to hairless and to the normal allele. It has been given the symbol hr_{rh}.

3. Rhino is very similar to the type of hairlessness described by Gaskoin,[6] Allen,[1] and Campbell,[2] and is thought to be a recurrence of the same condition.

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✦

'Ploids Among the Micro-Compends

For the McGraw-Hill Book Company, 1940 is the season for books on plant microtechnique. If the first one, by Donald A. Johansen (for review, see October 1940 Journal), exhibits *gigas* characters, then the second,* by Professor John E. Sass of Iowa State College, has the appearange of a haploid. The first, with 523 pages, tends to be encyclopedic and is, at the same time, both a text and a reference book; the second, with 222 pages, is primarily a training manual which has evolved "over a period of years of connection with the teaching of a college course in histological methods." The two books satisfy the present needs in this field.

Except for a preface bordering on wordiness, Professor Sass has written a well-organized, simple, concise, and forthright book. One feels it to be an honest expression of laboratory experiences. It is filled with helpful specific suggestions and criticisms. Part I (pp. 1-120) deals with general principles and methods; Part II (pp. 121-214) treats the "processing" of various tissues, organs, and representatives of the major plant groups and includes, also, a chapter on photomicrography and one on the construction, use, and care of the microscope. There are 35 text figures, about a quarter of which are photomicrographs. The chromosome receives so little attention that it does not appear in the index. Nor, for that matter, does the nucleus. "Mitochondria" is indexed.

This book gives a good introduction to the broad phases of botanical microtechnique.

J. T. Baldwin, Jr.
University of Michigan

*John E. Sass. *Elements of Botanical Microtechnique.* McGraw-Hill Book Company, Inc New York, New York. 1940. $2.50.

CROSSROADS IN CANCER RESEARCH*

LEONELL C. STRONG

Department of Anatomy, Yale University School of Medicine

WE are living in a world of optimism in the study of cancer. We believe that real progress is being made in fundamental cancer research, and that the solution to the problem will result primarily from two contributions, namely: (1) that cancer can be produced at will in experimental animals by the injection of pure chemicals, and (2) that spontaneous cancer can be obtained in experimental animals, under controlled conditions, by the application of the principles of genetics. This period of optimism has brought to the field of cancer research many new investigators. This trend has been so pronounced that the fear has been expressed that the contributions of so many specialists in so many branches of human knowledge would only lead to chaos. It is the purpose of this paper to point out that the paths explored by the many specialists are now beginning to converge into a very few roads and that the approach to the goal ahead, the solution of the cancer problem, is beginning to be, for the first time, clearly indicated.

Of the two main roads indicated above the first is, perhaps, the one better known to you. It had its beginning in clinical medicine, after which it split into four free branches, which recently have begun to join again. The experimental biologist took up the clinical lead, followed by the chemist, then the endocrinologist, and finally the geneticist. The key was supplied by Dr. Potts in 1775 when he pointed out that cancer of the scrotum in chimney sweeps constituted what we would call today an occupational disease. The soot with which those men came into contact appeared to be the inciting cause. More than a century later two experimental biologists determined that cancer could be produced in animals by the periodic application of a solution of coal tar. It was not long before chemists were able to demonstrate that the active carcinogenic agent in coal tar was a sterol derivative closely related to phenanthrene. From this observation chemistry has supplied us with a long list of other pure substances with characteristic and specific carcinogenic properties.

In the meantime it had also been learned that the body manufactures substances which are chemically related to these above mentioned carcinogenic sterols. One of these is the female sex hormone. The injection of this hormone into suitable animals has brought about the appearance of several types of tumors, as follows: (1) carcinoma of the mammary gland, (2) carcinoma of the cervix, (3) adenoma of the pituitary gland, (4) local sarcoma at the site of injection (?), (5) interstitial cell tumors of the testes, and (6) lymphoid tumors, both leukemic and aleukemic.

It had also been established as a fact that cancer of the mammary gland, and perhaps other types of tumors as well, can only be induced by the injection of the female sex hormone into a suitable individual — an individual which has been made susceptible to respond favorably to hormone injection by reason of his genetic constitution. For example, a variety of responses are brought about in different pure strains of mice by identical injections of hormones. A mouse belonging to a genetically susceptible-to-cancer-of-the-mammary-gland strain will give rise to that tumor; a mouse belonging to a resistant-to-cancer strain will not tolerate the hormone but will die of complications without any evidence of cancer formation. The production of a cancer by the injection of a pure chemical is not due to chance alone. It is also determined in part by constitutional factors in the animal, as is shown in pure strains of mice in which these factors have been standardized or fixed by genetic principles. In other words, the end result, cancer, is the resultant of many forces which have exerted an influence on the biology of the host for varying periods of time.

*Presented before the Annual Meeting of the New England Cancer Society, May 22, 1940.

But cancer, in the last analysis, is the product or response of the individual himself as a resultant of influences of a chemical nature which it receives (a) from the environment, or (b) manufactures itself.

This main highway started simply, but ramified into such complex by-paths that a unified picture seemed at one time a forlorn hope. Now the detours are beginning to come together, and it is becoming a veritable boulevard which is leading us toward fundamental contributions to the cancer problem.

Genic Reaction-Systems

The other main highway toward the study of cancer, which has had an entirely different origin, and, at present at least, may be leading in an entirely different direction, has absorbed contributions from genetics, chemistry and recent studies on viruses. To indicate this highway, I shall start with genetics.

As you know, the unit of physiological activity within the individual cell of the body is known as a gene. In embryonic development two or more genes set up an action-reaction system and as a result of this activity one or more adult characteristics of the individual are brought about. The adult individual is simply the sum total of these so-called unit characters. Now genes may change,—that is, they may mutate. When they do, changes in the action and reaction systems of the egg or embryo are brought about and the end result is that the adult individual is different in certain characteristics. But genes do not need to mutate in order to produce changes in the adult. Well established cases have been reported in which for some reason or other the spatial relationships existing between the genes are altered, and the end result is different. In addition to these intrinsic or genetic determiners being uniform, they must also act in a uniform environment. For gene action to be uniform, therefore, the cytoplasm in which the genes normally function must be uniform and the elements surrounding the egg must also be uniform. Among the environmental agencies that profoundly influence "gene action and reaction" are temperature and oxygen tension. That is, alterations in the oxidation-reduction relationships of the egg system may profoundly affect development. For example, there is a character in Drosophila called short wings, which is inherited as a simple sex-linked recessive under ordinary conditions. When the flies are raised at one temperature (14°C) during larval life all of the flies inheriting short wings are wild type or normal. When they are raised at a somewhat higher temperature (27.5°C) all of them show the short wing character. When the flies are raised at a still higher temperature (31°C) the inherited gene behaves as a lethal, since all flies bearing the gene die during larval life. Many other similar instances of the interaction of the gene-system of the organism with the environment could be cited.

Recent work by Caspersson on the application of the ultra violet microscope to the study of the chromosomes has disclosed the very important fact that bands characteristic of nucleic acids coincide very regularly with the cross striations which are assumed to be the loci for the genes. Now the nucleic acids are usually combined with a sugar and a protein in the architecture of the nucleus. For example, the true or euchromatin of the nucleus is supposed to be some combination of desoxy-ribose-nucleic acids. If this is so then embryonic development or physiological behavior of the cell is brought about by the interaction of spatially related nucleo-proteins. Several of the viruses that produce diseases in both plants and animals may be nucleoproteins. (In fact it has been maintained that a virus is simply a "naked gene," — that is, one that has been freed from cytoplasm. This idea, interesting as it is, may not be necessary in our present discussion.) If a new nucleoprotein, foreign to the cell, should somehow or other get into a living cell capable or reproduction, it would not be very difficult to conceive that it might set up a new chain or sequence of "action and reaction systems" with some of the genes of that cell (chemically related nucleoproteins). The

end result of such a novel reaction-system might be something different from normal cells, for example, cancer.

The main difficulty in the way of accepting this interesting concept for the origin of mammalian tumors is the fact that so far no filterable agent or virus has been demonstrated in typically malignant tumors of mice. In fact the Rous sarcoma in chickens and the Shope tumor in rabbits and a few others are the only ones so far demonstrated to be of a filterable nature.

In support of the concept that a nuclear change such as a shift in the action and reaction systems of the genes themselves, either occurring spontaneously or due to the presence of a foreign nucleoprotein, the following facts may be enumerated.

1. The presence of tobacco mosaic virus (a nucleoprotein) produces irregular cell divisions and other nuclear or chromosomal aberrations that are (a) either found in cancer tissue, or (b) may supply material for a genetically altered cell which may be a cancer cell.

2. Physical agents such as x-rays and ultra violet light that have a pronounced effect on chromosomal behavior also bring about changes that may lead eventually to cancer. It is a very interesting fact that the wave length of ultra violet light which induces mutations in plants (2600 Å units) is the same as the wave length absorbed in the pentose nucleotides of normal cytoplasm and the desoxy-ribose-nucleic acids of the chromosomes. No other wave length will have the same effect.

3. Transplantation studies have supplied two concepts of the nature of the cancer cell: (a) that the cancer cell is controlled by an intrinsic or genetic constitution, and (b) that the genetic constitution of the cancer cell has deviated from the genetic constitution of the cell of origin presumably by a process of somatic mutation.

4. Strains of mice may be classified in the same sequence according to: (a) intrinsic tendency of the females to give rise to or not to give rise to spontaneous tumors of the mammary gland, (b) shifts of hemoglobin per unit of time, and (c) tolerance to the anti-oxidant salicylic aldehyde. Casey and Pearce state that "From the results of the experiments here reported, it seems possible to predict with an accuracy of between 80 and 90 per cent the individual resistance or susceptibility of rabbits to the Brown-Pearce tumor by a study of their blood cells before inoculation (of which study the most susceptible animals were those which had, before inoculation hemoglobin above 70% or below 60% (Newcomer) etc." This indicates that a common factor is responsible for these seemingly unrelated phenomena.

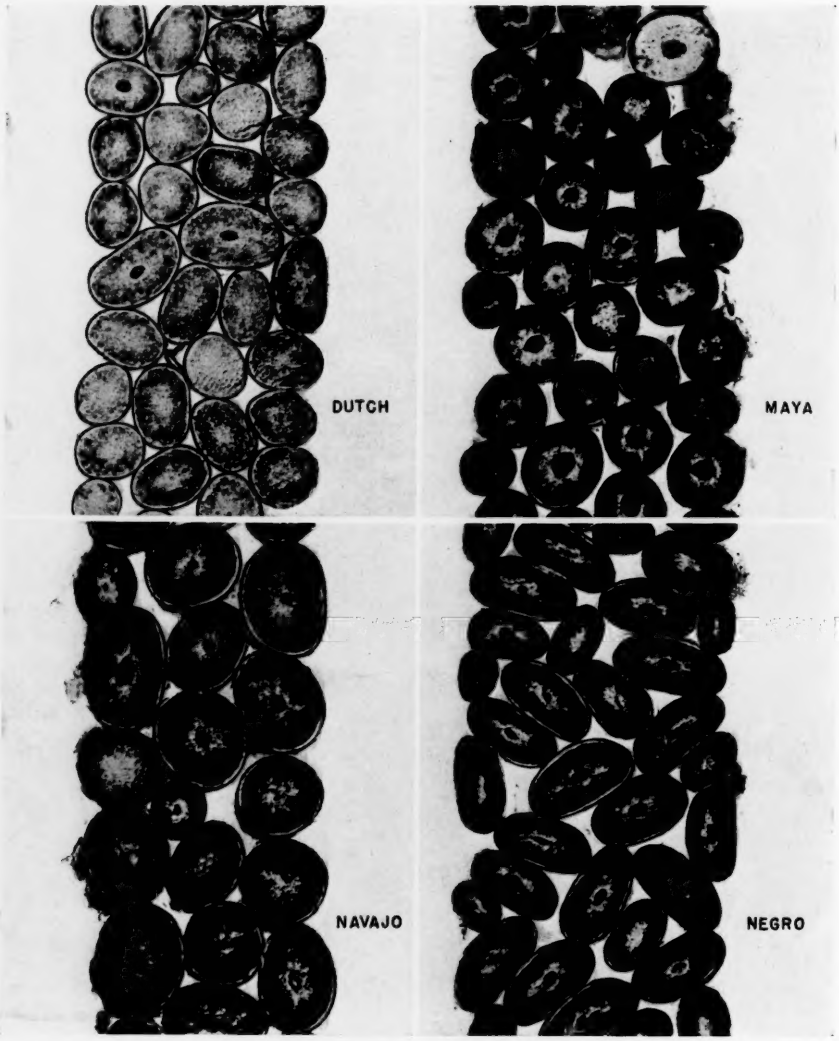
5. Studies on cell respiration, aerobic and anaerobic glycolysis, etc., have indicated that an alteration in the oxidation-reduction phenomena of the cell is a fairly consistent characteristic of malignancy.

It is thus clear that contributions of genetics, the pathology of viruses, chemistry and physiology are mapping out another broad highway leading to an interpretation of the origin of cancer.

Will a Superhighway Emerge?

It seems difficult to postulate how the two main highways, outlined briefly above, and made up of the contributions of many specialized fields, are ever going to converge into one single superhighway. Genetics and chemistry are the only two contributions common to both. This is probably due in part to the flexibility of the science of genetics and to the broad domain of chemistry as applied to living phenomena.

Perhaps it would not be necessary for the two main highways ever to cross. Some such concept as the following would make this unnecessary: that in the origin of cancer there are two complexes, (1) cancer or not cancer may be determined by the second highway — that of the oxidation-reduction phenomena of the cell, nuclear alterations, shifts in action and reaction systems of nucleoproteins, etc., and (2) specific types of cancer being determined by the first highway — that of the carcinogens and the hormones.



HAIR FORM OF FOUR RACES

Figure 2

Cross sections of hair from individuals of four racial groups, showing striking differences in shape and structure. These sections were made by a modification of the Hardy technique, a method so simple that it will be possible to survey the hair form of a large number of subjects. Statistical treatment of an adequate sample of the various racial groups would be necessary to determine the value of these differences in establishing racial origins. Magnified 185 times.

CROSS SECTIONS OF HUMAN HAIR FROM FOUR RACIAL GROUPS

MORRIS STEGGERDA
Carnegie Institution of Washington,
Cold Spring Harbor, N. Y.

LOCKS OF FOUR RACES

Figure 3

Can the statistical numbering of the cross sections of hair differentiate the races of mankind?

THE unique device for the rapid production of cross sections of animal and plant fibers, invented by Dr. J. I. Hardy,* has the advantage over the old embedding and microtome technique in that as many as 150 fibers can be sectioned at once. The device was invented primarily for use in the wool industry but it can be used also for making cross sections of human hair. The time required for making a permanent slide containing 150 cross sections may be as little as 10 minutes as compared with two or three days with the older technique.

The device is a small metal plate 3 inches long, 1 inch wide and 1/8 inch thick. It has a narrow slot 3/8 of an inch long into which can be packed 150 to 200 hairs, depending upon the thickness of the hairs, and the degree of tightness with which they are packed. The hairs are washed in carbon tetrachloride, dried and packed into the slot. Then they are cut off even with the metal plate, on both the top and bottom

*Hardy, J. I. A practical laboratory method of making thin cross sections of fibers. Circular 378, U. S. Dept. Agric., Washington, D. C. 1935.

The technique as outlined by Dr. Hardy was followed and somewhat refined by two assistants in the Department of Genetics of the Carnegie Institution of Washingon, namely, Mrs. Ruth B. Eckardt and Miss Barbara Korsch. For their assisance the author expresses his thanks.

sides of the plate. They are then pushed partly through the fiber slot by means of a metal screw. Thus by turning the screw, the depth of the cross sections can be regulated. This layer of protruding hair tips is then coated with a thin solution of celluloid (11 gms. celluloid, 40 c.c. acetone and 20 c.c. amyl acetate). When the solution hardens, it, containing the hair sections, is cut off with a sharp razor blade, and the resulting strip mounted in Euparal or Canada Balsam.

In Figures 2 and 3 are shown tufts of hairs from four racial stocks, along with photographs showing corresponding cross sections. From the photographs it will be seen that the size and shape of the cross sections of the individual hairs from a given person's head vary widely. Also, the Dutch hairs shown in this illustration are considerably lighter in pigment than those of the other races. The one light cross section in the Maya slide represents a white or gray hair. The Negro hairs being kinky are more eliptical than the Dutch; those from the two Indians, representing two different racial stocks, both of which have straight hair, are definitely more circular.

Measurements are being made on 100 hairs from each individual and an adequate number of persons from each of these races. From these statistics, the individual variation in hair form will be determined as well as statistical racial differences in hair size and shape will be made available. This article merely shows the possibilities of research in hair form with the use of this technique.

✦

CORRELATION IN EGG WEIGHT BETWEEN MOTHERS AND DAUGHTERS

F. A. Hays

LINES *A*, *B* and *C* were selectively bred through nine generations for egg size. All birds were Rhode Island Reds. Line *A* was bred from small egg size. Line *B* was bred for medium egg size. Line *C* was bred for large egg size. Full brothers were used to sire the three lines each year so that selection was based on the egg size of the dams. Nine generations were produced in each line. All egg weight records were taken in the pullet year when the birds were 11 to 12 months of age to avoid seasonal and age variability. Regression was found to be non-linear in all lines, so that the correlation ratio expresses the relationship.

The constants arrived at were as follows:

	Line A	Line B	Line C
Total Dams	25	31	28
Total Daughters	235	265	236
Mean Egg Wt. of Dams—(Grams)	57.07	60.11	59.59
Mean Egg Wt. of Daughters—(Grams)	57.25	59.15	59.37
Correlation Ratio	.4710	.5272	.4009

The fact that the regression of daughters' egg weight on mothers' egg weight was non-linear in all three lines was probably due largely to the heterozygous nature of the mothers for the series of genes affecting egg size.

The correlation between mothers and daughters was significant but not intimate and of about the same magnitude in all lines. This fact lends support to the hypothesis that genes affecting egg size are autosomal.

COLCHICINE INDUCED TETRAPLOIDS IN DIOECIOUS AND MONOECIOUS SPECIES OF THE AMARANTHACEAE*

MERRITT J. MURRAY
Cornell University, Ithaca, New York

NUMEROUS examples of tetraploid plants have been reported since Gates discovered that the gigas mutant of *Oenothera lamarckiana* had a tetraploid chromosome number[2]. Some of these were found in genetic cultures; while others were discovered existing in nature. The majority are known in hermaphroditic species, primarily in the monoecious and perfect-flowered forms. Tetraploidy in dioecious organisms, either plant or animal, is of rare occurrence. Muller[4] and Dobzhansky[1] (p. 219) have discussed the reasons for the low frequency of polyploidy in dioecious organisms as compared to hermaphroditic ones. Their conclusions are that the mutation is unlikely to occur simultaneously in both sexes with great enough frequency to insure inbreeding and that even if this did happen, tetraploid individuals breeding together, or with diploids, would lead to intersexual or sterile types due to complications with the sex-determining mechanism.

Verification of these ideas is needed for dioecious plants. Recently Warmke and Blakeslee[8,9,10] have obtained triploid and tetraploid plants of the dioecious species, *Melandrium dioicum*. Their findings will be discussed in relation to the data which I am reporting for the dioecious species, *Acnida tamariscina* (Nutt.) Wood.

Method

All attempts to get tetraploid chimeras by the use of the graft and callus method proved unsuccessful. The use of colchicine has given excellent results.

Treatment of the seeds of *Acnida tamariscina* in a 0.25 per cent aqueous solution of colchicine for 60 hours induced the typical swollen appearance of the germinating seedlings. One hundred and ten plants were potted and approximately half of these died without any appreciable growth. Of the remaining, three plants were selected as being almost wholly tetraploid. Two were females; one was a male. These grew into large plants in about eight months' time and on inbreeding produced an abundance of seed.

One application of a 0.25 per cent aqueous solution of colchicine applied to the growing points of the monoecious species *Amaranthus caudatus L.* and *Amaranthus hybridus* L. gave positive results. Only two plants of each species were treated.

Sex Ratio of the Dioecious Tetraploids

Murray[6] has shown from genetic evidence that the male plant of *Acnida tamariscina* is the heterogametic sex. Doubling the chromosome number of an *XX* female to an *XXXX* one does not change the sex. Likewise, the *XXYY* type is a normal male with fertile pollen.

The next generation progeny consisted of 131 females and 1,633 males or about 12 males to every female. This is in contrast to the diploid parent which gives a normal 1:1 sex ratio (2259 ♀ ♀ :2291 ♂ ♂ D/PE = .75).

Warmke and Blakeslee[9] also found a high proportion of males (67 ♂ ♂ : 3 ♀ ♀) in the second generation tetra-

*Paper No. 232, Department of Plant Breeding, Cornell University, Ithaca, New York.
The author is indebted to Professor R. A. Emerson and Professor L. W. Sharp for their guidance throughout the problem and to Professor L. F. Randolph for criticism of the manuscript.

DIPLOID AND DOUBLE-DIPLOID PLANTS OF ACNIDA

Figure 4

Colchicine treatment of the dioecious species of *Acnida* makes possible new approaches to the problem of sex in plants. The effects on growth habit of doubling the chromosome number in *Acnida tamariscina* are shown here. *A* shows diploid and tetraploid males, and *B* diploid and tetraploid females of this species. Crossing diploids and tetraploids gives triploid forms and inbreeding of these triploids should give diploids with extra chromosomes. Thus by colchicine treatment it is possible to observe how the sex-chromosome balance affects sex expression in this group of plants.

ploids of *Melandrium dioicum*. Since this species has a conspicuous heteromorphic sex chromosome pair, they were able to demonstrate that 65 of the males were of *XXXY* constitution and two were like the parental form, *XXYY*. Their cytological observations on the *XXYY* males showed that bivalent association of *X-X* and *Y-Y* is much more frequent than *X-Y* and *X-Y*; and that two types of quadrivalent association also resulted in the formation of a high proportion of *XY* gametes and a correspondingly low proportion of *XX* and *YY* gametes.

My genetical results are readily interpretable in the same manner as those found for *Melandrium*. The proportions of *XXYY* male individuals and of *XXXX* female individuals should be equal in the second generation progeny. Thus, the total population of 1,764 tetraploids consisted of approximately 1,502 *XXXY* males, 131 *XXYY* males, and 131 *XXXX* females. Since the *XXYY* and *XXXY* males are identical in appearance, proof that the *XXXY* males exist must come from the results of crossing both types of males to the same female. Crosses with the *XXYY* males should repeat the ratio of 1 ♀ :12 ♂ ♂ already obtained; while crosses with *XXXY* males should be expected on theoretical grounds to give a ratio of 1 ♀ :1 ♂. The progeny of two crosses have been studied and both show 1:1 sex ratios (84 ♀ ♀ :64 ♂ ♂ and 22 ♀ ♀ : 32 ♂ ♂). The investigation of a larger number of crosses should demonstrate that some *XXYY* males were present and that they repeat the ratio of 1 ♀ : 12 ♂ ♂.*

From the above data, one can compute that approximately 85 percent of the gametes produced by the *XXYY* male were of *XY* constitution. These results are in good agreement with Warmke and Blakeslee's cytological observations on *XXYY Melandrium* males since they found 86.25 percent of the bivalent and quadrivalent associations would result in *XY* gametes. These authors omit from consideration five percent of unusual associations of which they do not specify the exact nature.

Somatic counts on several plants show that these plants have a tetraploid ($4n = 64$) chromosome number. Careful observation of the morphological characters of these plants and also an inspection of the pollen of all the male plants lead me to conclude that deviations in chromosome number from that of a normal tetraploid complement are probably infrequent. No sex abnormalities of any kind have been observed.

Pollen abortion is usually less than one or two percent. Although diakinesis material is poor in this species, observations on two plants indicate that bivalent association is most common with usually not more than one or two quadrivalents. The females set an abundance of viable-appearing seed, and a pure-breeding tetraploid dioecious race with an equality of males and females has been established. Warmke and Blakeslee[10] have also established such a race in *Melandrium*.

The sex of the tetraploid races of the two monoecious species is unchanged from that of the diploid species.

Morphological Characteristics

Cotyledons and leaves of the tetraploid plants of *Acnida tamariscina* are larger, broader, thicker and of a darker green color than those of the diploid (Figure 4 *A, B*). Tetraploid leaves also have larger stomata.

The tetraploid inflorescence is thicker, heavier, and more crowded than that of the diploid due to the increased size of the individual tetraploid flowers (Figure 5). The tetraploid staminate flowers have larger sepals, stamens, and pollen grains than those of the diploid. Pistillate flowers are larger in the tetraploid and this increase in size characterizes the various parts of the flower, including the

*Twelve additional crosses have been grown. Ten gave 1:1 sex ratios (140 ♀ ♀ :148 ♂ ♂); two gave ratios of approximately 1 ♀ :12 ♂ ♂ (5 ♀ ♀ :38 ♂ ♂). Hence, of the 14 ♂ ♂ which were tested, 12 were of the *XXXY* type and two were of the *XXYY* type.

stigmas, ovary, and ovule. The size of the seed is also larger in the tetraploid than in the diploid (Figure 6).

The size of the mature tetraploid plants was not determined. These plants were transplanted to the field plot July 10 and this is too late in the season for this species to attain maximum size since the time of flowering is determined by a short photoperiod. Comparison with diploids of the same age indicates that the tetraploids probably grow more slowly, have a shorter, thicker stem and take slightly longer to flower. The tetraploids appeared to withstand the severe drought conditions as well as the diploids.

The tetraploid plants of the monoecious species *Amaranthus caudatus* and *A. hybridus* in comparison with the diploids have larger leaves, cotyledons, stomata, flowers, stamens, pollen grains, utricles, stigmas, ovules, sepals, and seeds. Photographs of the tops of diploid and tetraploid *A. caudatus* plants are shown in Figure 7. There is very little difference in plant size but the tetraploids flowered about a week later than the diploids.

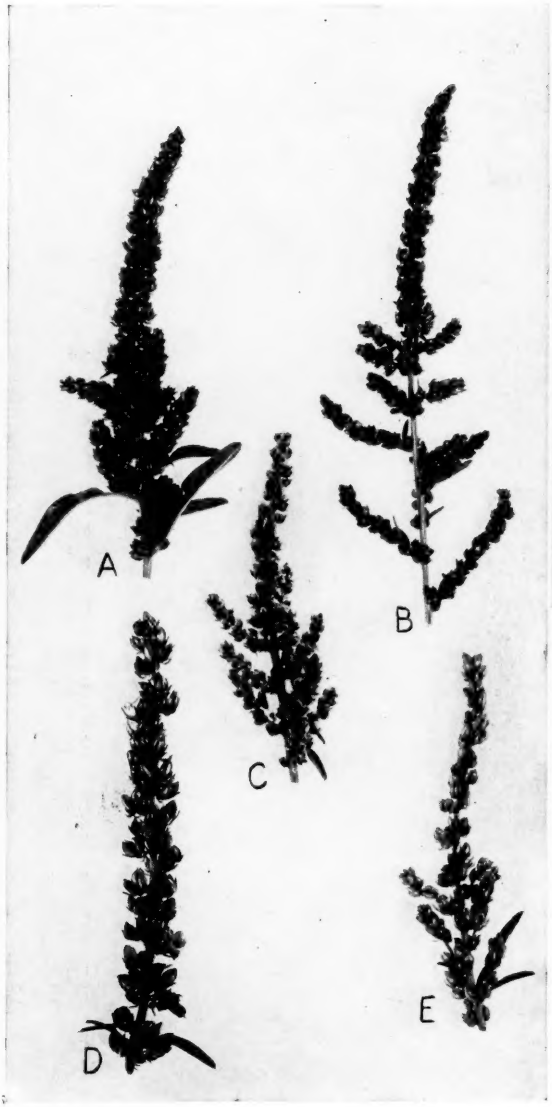
Dioecious Triploids

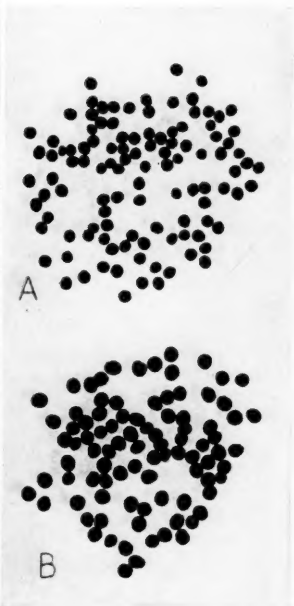
Triploid *Acnida* plants have been obtained from the cross $4n$ ♀ $(XXXX) \times 2n$ ♂ (XY) and also from the reciprocal cross $2n$ ♀ $(XX) \times 4n$ ♂ $(XXXY$ or $XXYY)$. Of the 60 plants observed, 32 were females, 27 were males and one was monoecious. The females are presumably of XXX constitution; the males of XXY constitution. These results might be expected, since it has been shown that one Y chromosome is epistatic to three X chromosomes in the $XXXY$ males where the autosomes are in a balanced condition.

Exact chromosome counts of five females and two males have been made. The other plants in this cross are approximately triploid in constitution. The males exhibit considerable variation in the amount of pollen abortion (20-90 percent). Murray[6] has shown that the diploid race of *Acnida tamariscina* used in the creation of the $4n$ race segregates for a factor inducing 50 percent pollen abortion when heterozygous. The constitution of the $4n$ race in regard to this factor is unknown. It is probable that part of the aborted pollen in certain $3n$ ♂ plants is due to the heterozygous nature of this factor rather than to incompatible gametes resulting from the normal segregation of chromosomes in a $3n$ plant.

The exceptional monoecious plant appears phenotypically to be a modified male. In normal monoecious species of the genus *Amaranthus,* both pistillate and staminate flowers have a fully developed five-parted calyx. In the dioecious species of *Acnida* the staminate plants have the flowers with the calyx fully developed. The pistillate plants have flowers lacking a perianth, although the rudiments are present and occasionally develop to some extent. This exceptional plant bore staminate flowers with a calyx, pistillate flowers with a rudimentary calyx and more or less perfect flowers with a fully developed calyx. Part of the perfect flowers had rudimentary female reproductive parts developing in the center of the flower which is the normal position. Other flowers had stigmas on the ends of stamens or on the filament in the position of an anther. Pollen from this plant should be functional since only about 50 percent of the pollen is visibly aborted. The pistillate flowers appear normal but dehisce readily, apparently soon after reaching maturity. This is a characteristic of staminate flowers in both monoecious and dioecious species as they dehisce a few days after shedding their pollen. No seeds were obtained from selfing this plant.

Murray[6] has reported the infrequent occurrence of more or less perfect flowers in diploid males grown under the extreme environmental conditions of low light intensity and low temperature. The same plants grown under summer conditions were normal males. Although these perfect flowers were pollinated, all dehisced in the manner of a staminate flower. The intersexual condition of the exceptional $3n$ plant may likewise be due to environmental causes. While grow-





FLOWER SPIKES OF NORMAL AND MULTI-CHROMOSOME TYPES

Figure 5 (at left)

Small branches of the inflorescence of *Acnida tamariscina*. *A*—Tetraploid (*4n*) pistillate branch bearing seeds; *B*—Diploid (*2n*) pistillate branch bearing seeds; *C*—*4n* unpollinated pistillate branch; *D*—*4n* staminate branch; *E*—*2n* staminate branch.

SEEDS LARGER

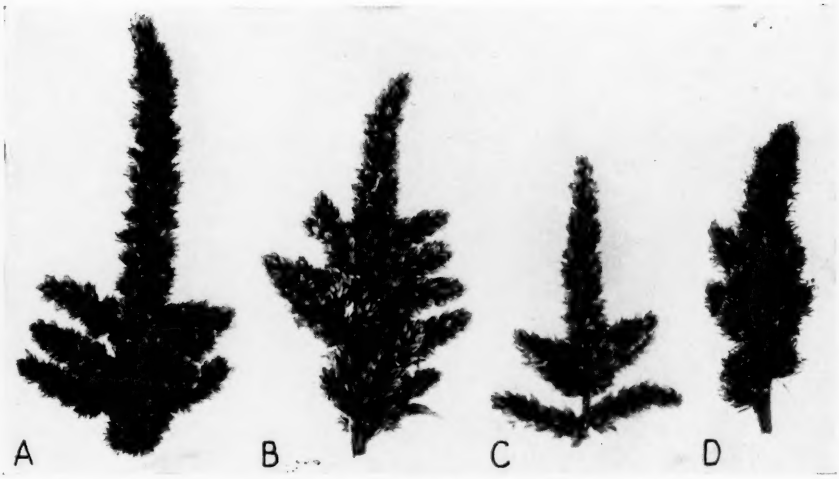
Figure 6 (above)

Seeds of diploid (*A*) and tetraploid (*B*) plants of *Acnida tamariscina*.

DIPLOID, TETRAPLOID, AND DOUBLE-DIPLOID

Figure 7

Tops of: *A* — Diploid *Amaranthus caudatus; B* — of Tetraploid *A. caudatus;* and *C* — Amphidiploid *A. caudatus* × *A. retroflexus.* The hybrid between these two species is a vigorous plant but completely sterile. When the chromosomes of this sterile hybrid are doubled by colchicine treatment, the resulting amphidiploid, having two sets of *caudatus* and of *retroflexus* chromosomes, is fertile. The progeny are uniform and as vigorous as the initial amphidiploid.



SMALL BRANCHES OF INFLORESCENCE

Figure 8

A — Amphidiploid of *Amaranthus caudatus* × *A. retroflexus; B* — 4*n A. caudatus; C* — 2*n A. caudatus; D* — 2*n A. retroflexus.* The double diploid (*A*) and the tetraploid (*B*) have larger flowers and seeds than either of their diploid parents.

ing under a winter greenhouse environment, this plant had a considerable number of pistillate and more or less perfect flowers. Now, in the latter part of May, it is entirely staminate.*

Amphidiploids

Amaranthus caudatus crossed to *Amaranthus retroflexus* gave highly sterile but very vigorous F_1 hybrids. One of these hybrids following colchicine treatment gave 106 amphidiploid progeny. All plants were perfectly fertile, phenotypically alike, and one plant has bred true the second generation.

Are these amphidiploids large and vigorous due to the mere doubling of the chromosome number or are they large due to "permanent" heterosis? While the F_1 hybrids are vegetatively more vigorous than either parent, the objection may be made that since they are sterile, they continue vegetative growth after flowering. This is true. However, the F_1 hybrids were larger than either parent at the time an inflorescence was developing. *Amaranthus retroflexus* ($n = 17$) is the smaller parent and a tetraploid race has not been established in this species. *Amaranthus caudatus* ($n = 16$) is much larger and a tetraploid race has already been described. Comparisons may thus be made between the amphidiploid ($4n = 66$) and a tetraploid ($4n = 64$) race of the larger species.

In plant size, the amphidiploid was much larger than the tetraploid (Figure 7). This may be judged from the relative sizes of their leaves (Figure 7). The same conclusion is true of the flowers (Figure 8). The most measurable characters are the seeds since these involve no selection on my part, and are probably least subject to environmental fluctuations. Seed weights are given in Table 1.

The tetraploids of *Acnida tamariscina* and *Amaranthus caudatus* show approximately a 50 percent increase in seed

*Eight cuttings of this plant were grown under field conditions during the summer and these plants produced only normal staminate flowers.

weight over that of the diploids. The amphidiploid seeds weigh slightly less than those of the tetraploid *Amaranthus caudatus*. However, the total yield from an amphidiploid plant is probably greater than that of a tetraploid plant since the former exhibited greater vegetative vigor than the latter. The tetraploids of two species show about the same percentage increase in seed volume over that of their diploids. It should be remembered that the sterility in all these $4n$ types is very low.

Discussion

Tetraploid males and females have been created experimentally in *Drosophila melanogaster, Rumex acetosa, Melandrium dioicum,* and *Acnida tamariscina*. Diploid male and female gametophytes have been observed in *Sphaerocarpus donnellii*.

Warmke and Blakeslee[10] reported the establishment of a tetraploid race in *Melandrium* which gives an approximate equality of males and females. A $4n$ race of *Acnida tamariscina* with excellent fertility and a 1:1 sex ratio has been described in this paper. A pure-breeding tetraploid race of *Rumex acetosa* has apparently not been reported and probably is not possible. Yamamota[11] summarized the euploid and aneuploid types that have been observed. Presumably, the cross of a tetraploid female $(4X + 4A)$ to a tetraploid male $(2X + 4Y + 4A)$ would usually result in the production of $3X + 2Y + 4A$ plants which have been shown to be intersexes. Dobzhansky[1] stated that the cross of a tetraploid Drosophila female $(4X + 4A)$ to a tetraploid male $(2X + 4A)$ would be expected to give intersexes of $3X + 4A$ constitution. Mackay and Allen[3] reported diploid male $(2Y + 2A)$ and female $(2X + 2A)$ gametophytes in *Sphaerocarpos* but they have not observed a balanced tetraploid sporophyte. Such a sporophyte $(2X + 2Y + 4A)$ composition might be expected on theoretical grounds to produce mostly $X + Y + 2A$ gametophytes which Mackay and Allen have shown to be intersexual.

There seems to be an essential difference involved here. The male factors are seemingly localized in the autosomes in *Drosophila* and *Rumex*, whereas Warmke and Blakeslee[10] believe they have evidence, from a study of chromosomal balances, proving that the male factors are present in the Y chromosome. The male factors appear to be located in the Y chromosome in *Acnida*. Murray[6] has shown that a cross of an *Acnida* female to a monoecious species gives only females and that the reciprocal cross gives an equality of males and females. The genotypes of these F_1 hybrids may be designated as:

F_1 ♀ Hybrid
Acnida ♀ genom $(1X + 15A)$
Monoecious genom (16 chromosomes)
F_1 ♂ Hybrid
Acnida ♂ genom $(1Y + 15A)$
Monoecious genom (16 chromosomes)

Since the monoecious species do not segregate for sex differences on inbreeding one may conclude that the monoecious genom in both hybrids is identical. A direct comparison of the $1X + 15A$ and $1Y + 15A$ genoms obtained from the dioecious species is thus possible. Presumably, the autosomes either do not carry sex factors or if they do, are homo-

TABLE I.—Comparison of Seed Weight and Size of Several 2n and 4n Races

Type		Weight in grams of 1,000 seeds		Volume in c.c. of 1,000 seeds		% increase of 4n over 2n	
		Sample		Sample			
		1	2	1	2	Weight	Volume
Amaranthus retroflexus	2n	.310	.305	.385	.38		
Amaranthus caudatus	2n	.455	.472	.59	.61		
Amaranthus caudatus	4n	.720	.720	1.00	1.00	55	67
Amphidiploid	4n	.695	.700	.915	.92		
Acnida tamariscina	2n	.245	.220	.32	.27		
Acnida tamariscina	4n	.350	.357	.49	.51	52	69

zygous for them, since in the dioecious species segregation does not occur on inbreeding. Thus the differential factors determining maleness and femaleness under normal environmental conditions are probably located in the *XY* chromosome pair. This cannot be considered absolute proof that the *Y* chromosome carries the male-determining factors. However, if the *Drosophila* type of sex inheritance were true of *Acnida*, one should expect the *XXXY* $(3X + 4A)$ tetraploid *Acnida* males to be intersexes.

Polyploidy may result in the production of intersexual progeny in species with a particular type of sex mechanism (*Drosophila* and *Rumex*), while in other species with a different type of sex mechanism (*Melandrium* and *Acnida*), normal progeny are obtained. Of these two types of sex mechanisms, the latter is apparently the simpler one and probably the more primitive one.

Under natural evolutionary conditions, *Acnida tamariscina* conceivably might develop a tetraploid race following the simultaneous occurrence of the mutation in both sexes and their subsequent inbreeding. Muller and Dobzhansky's conclusion that this would occur most infrequently seems warranted. However, a 4*n* race might be established from a single mutation through the production and inbreeding of triploids. The viability and fertility of 3*n* Acnida plants demonstrates that this is a distinct possibility.

The fact that so few examples of polyploidy have been observed in dioecious plants is very probably due to a number of causes. Randolph[7] has shown that pollen from 4*n* Zea plants will not compete successfully with that from 2*n* plants when both are placed on the silks of 4*n* plants. Without some degree of isolation, pollen competition may be an important factor in preventing the evolution of polyploid dioecious races.

Summary

Colchicine-induced tetraploids have larger cotyledons, leaves, stomata, pollen grains, ovules, stamens, flowers, and seeds than the diploids.

In *Acnida tamariscina*, the cross of an *XXXX* female to an *XXYY* male gave a sex ratio of 131 ♀ ♀ : 1,633 ♂ ♂. This excess of second generation males has been explained on the basis of a high percentage of *X-X* and *Y-Y* synapsis of the *XXYY* males. The high proportion (85%) of *XY* gametes, so produced, results in many *XXXY* plants which are males. All plants are fertile and without sex abnormalities. Intersexuality is not a barrier in this dioecious species to the production of a tetraploid race, as the cross of an *XXXX* ♀ to an *XXXY* ♂ results in a pure-breeding race with a normal 1:1 sex ratio. Triploid males and females have also been obtained in *Acnida tamariscina*.

The tetraploids of two monoecious species are fertile and exhibit no changes in sex. Comparisons are made between an amphidiploid and a 4*n* race of one of its parental species.

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GENETICS OF HORNS IN SHEEP

THIS subject has been twice discussed in this JOURNAL in the past year, first by Warwick and Dunkle and more recently by Ibsen and Fox. The discussion and data contained in the first paper served notably to clarify the confused situation previously existing in the literature concerning horn inheritance in sheep, but the second paper has left the situation more confused than ever. Is it possible to bring order out of this confusion?

1. There are still in central and northeastern Asia and in north-western America several related species of wild sheep. Both sexes bear horns but the horns of the females are much smaller than those of the males. 2. Around the Mediterranean and in the islands of Sardinia and Corsica occur two or three related species of wild sheep of smaller size, in which the males have well developed horns but the females are regularly hornless, though Lydekker reports that an occasional Mouflon female has small horns.

It is generally believed that the merino sheep which originated in Spain is a domesticated Mouflon. Like the Mouflon of Sardinia and Corsica it regularly has horned males and hornless females. The sheep of Great Britain, of which there are many distinct breeds, are thought to have been derived also in large part from the Mouflon, though there are some indications of an origin in part from domesticated sheep introduced in prehistoric times from central Asia. Among these British breeds three different categories exist as regards horn development.

1. In blackfaced sheep of the Scottish highlands and in the mountain sheep of Wales and in the improved English breed known as Dorset Horned, as well as in several other breeds, both sexes bear horns but those of females are much smaller. This would seem to be a persistence under domestication of the original horn condition characteristic of the wild sheep of central Asia. The only alternative would be to suppose that by a reverse mutation Mouflon derivatives had reacquired the ability to develop horns in females.

2. In some other British breeds, including Merinos, the condition is the same as in the Mouflon; males have well developed horns, females are hornless.

3. In many other British breeds (Leicester, Lincoln, Hampshire, etc.) both sexes are hornless. This is to be regarded, it is generally admitted, not as an ancestral condition but as a consequence of a retrogressive or loss mutation of horns similar to that found in polled breeds of cattle.

A fact insufficiently emphasized in either of the papers under review, is the important part taken by the male sex hormone in horn development in sheep. If we assume (1) that there is a gene for the production of horns in sheep (and this assumption seems unavoidable in view of the existence of a mutation to hornlessness), then we must assume further (2) that the male sex hormone is a necessary factor in the development of horns in such breeds of sheep as have hornless females. For it is well known to every experienced sheep farmer that Merino wethers (males castrated as lambs) are hornless like ewes, although uncastrated males develop horns. It is clear also that even in breeds which are horned in both sexes, as are most wild species of sheep, the male sex hormone plays an important part in horn development, since the horns of males are much larger than those of females.

The facts presented by Warwick and Dunkle indicate that there is a single principal gene involved in horn development in sheep, and that this exists in the form of three alleles corresponding with the three conditions found in British breeds of sheep. (1) One allele, the original and most potent one (designed

*The assumed allele (*P*, polled) is improperly designated by a symbol different from its normal horn allele. The same basic symbol should be used for both, with only such differences as would serve to show their distinctness.

H' by Warwick and Dunkle) produces horns in both sexes, though male sex hormone greatly increases the effect, since males have larger horns than females. (2) A second allele, h, of lesser potency, is able to produce horns only in the presence of male sex hormone, so that males only bear horns. (3) A third (and weak) allele, H, does not permit of horn development, even in males.

Heterozygotes between these alleles may produce intermediate phenotypes, as is commonly true in multiple allele series. This may explain minor variations in horn development described as knobs, pits, and scurs, although interaction of the horn gene with other genes may possibly be involved.

The triple allele hypothesis accounts satisfactorily for the three standard conditions occurring among breeds of domestic sheep, and for the consequence of crosses between these three types, as shown by Warwick and Dunkle.

Compared with this analyses, that of Ibsen and Cox is complicated and obscure. It involves the assumption of two independent genes which inhibit horn development (P^* and Ih), one being an allele of the horn gene, the other not. There is satisfactory evidence for only one, the allele of the gene for normal horn development. Two other independent genes are invoked to explain variations in horn development, a horn modifier (Hm) and a gnee for scurs (Sc). Whenever a minor variation in horn development is observed, these authors think it necessary to invoke a gene for the modification, overlooking the possibility of gene interaction as an adequate explanation.

The triple allele hypothesis is to be preferred (1) for its simplicity, (2) for its exact correspondence with the three different conditions found among pure breeds of sheep and (3) as an adequate explanation of the consequences of making crosses between these three types.

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W. E. Castle
University of California

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Knight Dunlap Quixotes (Homemade) Genetic Windmills

At a time when there is urgent need for a scientific approach to many problems which perplex us, it is disconcerting to find a leader in experimental psychology crucifying the scientific method to cure disease. The disease under treatment is mental; the cure (Ripley may believe it or not), is to deny human heredity.

This neatest scientific trick of the year was performed in the September, 1940, issue of the *Scientific Monthly* by Dr. Knight Dunlap whose accomplishments in experimental psychology are widely recognized.

The motive for Dr. Dunlap's lapse from the scientific approach was humanitarian and hence understandable. Certain people — we might suspect they are a bit more neurotic than the average — fall victim to "genetophobia," a strange and alarming new disease whose symptoms Dr. Dunlap dramatically portrays. Others worry about rhythm, vibrations, soul waves, etc., but we do not deny the existence of radios, piano strings and night club orchestras or clairvoyants, to prevent those worries. Anyone likely to know anything about genetics has had interviews in person or by letter with such unfortunates. They have forsworn the pleasures of marriage and/or the possibility of offspring, and some of them are even prepared to forswear life itself, because Great Aunt Susan had bats in the belfry.

Some of these cases may well arouse our sympathies. About others, one is not so sure. The mental processes whereby such folks arrive at the conclusions they do suggests that the be-batted Great Aunt Susan is a convenient escape-fiction, who should not be too closely examined. (See Popenoe, Paul, Motivation of Childless Marriages, this Journal, December, 1936.)

So het up does Dr. Dunlap become over the mental anguish which the occasional genetophobes suffer that he seems almost eager to throw human genetics overboard to cure them. He has not seriously considered the possibility that some of his patients may have been deluded as to the truth in their own cases. He is very earnest about the tortures the genetophobe endures, and he does a thorough job in developing the need for the completely irrational cure he proposes for the disease.

He begins with the Kallikaks and the Jukes,

an endeavor which might get more than a ripple of approbation from the geneticists in the audience if he had done an adequate job. Unfortunately Dr. Dunlap's reasoning seems none too sound. In discussing the Kak-alliance of the affectionate Martin, Dunlap says, "how do you know the girl was feebleminded? Did anybody test her and assign an I.Q.?" Of course not, since Binet was not to astound the psychological world for several generations. But long before the stirring days of 1776, people knew how it was with half-wits. Shakespeare and the King James Version refer to "half-wits" and to "feebleminded." The Greeks also had a name for that misfortune. It is not necessary to measure the depth of the ocean before you can prove it exists, and people starve just as fast without knowing about vitamins and calories if the food runs out. The Kallikaks and Jukes are a bit on the bedtime story side, for sounder reasons than for lack of a mental tester at Valley Forge.

Having got himself into a fine lather disposing of the alleged "phantasies" Dr. Dunlap really warms up to his subject and lays about him with a right good will; "Psychologists find no difficulty in resolving the difficulties of neurotic or perturbed youngsters who seek their advice. For the benefit of the layman, it may be worth while to summarize the psychologist's procedure. In the first place he points out that nothing is really known about human heredity except that certain states such as red hair, haemophilia, and Presbyterianism, 'run in families'." The victim of these harrowing delusions is reassured when the genetic devils are thus roundly exorcised by a method which is questionable to say the least. The genetic corpus delicti is hysterically stamped upon, beaten and kicked for several pages before it is considered to be "liquidated"!

Surely this is only a beginning in this newer mental therapy. This means of casting out devils of fear and apprehension has vast possibilities, extending far beyond the borders of genetics. Those who have an unreasoning fear of falling from high places should also be given peace. Tell them that Newton's struggle with the apple was mere twaddle, — the gravitation concept just the brain-storm of an ancient nincompoop bent on frightening children. Tell them if they don't believe it, to try stepping off a high building and their fears and perplexities will be permanently resolved. They will be too, if the building is high enough. Tell those with claustrophobia that tunnels and closed places don't exist. Or if they can't comprehend that, let them get a job in a soft coal mine about the time one of the periodic disasters is due. An extension of this principle will teach that fire is not hot, ice is not cold, water will not drown and strychnine will not cause fatal muscle spasms. If we are really going to out-Eddy the immortal Mary Baker, let's really get busy with that most ancient magic of all—the magic of words. "Caldron, caldron, boil and bubble"!

Dr. Dunlap's verbal cavortings would be merely good clean fun if they were not so cruel. One could dispose of his unfortunate blast by a solemn review of the literature available, but even Dr. Dunlap does not need such an education, for he says, ". . . . One of the major duties of psychologists in the service of society, is to combat the popular superstitions about human heredity, *to point out that while all human traits, without exception, are hereditary in the modern scientific sense of the term* [italics reviewers'], we know nothing as yet about the mode or details of inheritance of important traits." Which pretty completely boxes the compass, and if his sufferers from genetophobia aren't half-wits they ought to begin seeing snakes on the wall at about this point in the argument.

To go from the newer psychological approach to its applications to actual cases, a tragic letter recently received shows how it works. The woman who wrote it married a blind man on the assurance of several doctors that none of her children would be blind. She had five and they are all blind. That is rather a ghastly joke on someone — either the doctors, or the woman, or Dr. Dunlap. Perhaps on all of them, but the woman did not seem to be amused. This grisly anecdote should let Dr. Dunlap sleep more soundly at night, after a quiet chuckle over the case of disposing of those silly "superstitions."

A crab-clawed man in Boston was assured at the hospital that his defect was not hereditary. He married and now has two crab-clawed children.

A microphthalmic man in Pennsylvania was assured by a skeptical medical man that microphthalmia was not hereditary. He also married and now has three children, all of whom are microphthalmic and blind.

A hydrophthalmic teacher in a blind school in the Middle West consulted a famous ophthalmologist in Chicago before deciding whether or not to marry. The eye specialist also used Dr. Dunlap's technique. The defect in the man's germplasm was argued out of existence. But today this blind man's only child is ophthalmic and blind in spite of the psychological therapy of the denial of genetic transmission practiced on the father.

You may be able to argue a defect out of a man's mind, but unfortunately for the offspring, defective genes seem to be beyond verbal exorcism. These defects aren't mental or emotional: neither are they "red hair, haemophilia or Presbyterianism." Like scores of other human characteristics, they follow a Mendelian pattern.

We cannot deny the existence of the disease of genetophobia, but we ought to be careful not to employ the phantasy of negation in order to effect its cure. To pretend that morbid genes do not exist will wreck many more lives than it will save, aside from being a method based upon deliberate misrepresentation.

Clyde E. Keeler
Robert Cook

RELATION OF FUZZ PATTERN TO LINT IN AN UPLAND COTTON CROSS*

J. O. WARE†

THERE are two kinds of fibers on a cotton seed: the long filaments which give cotton its value as a textile, and a short fuzz attached to the seed-coat of the fuzzy seeded varieties. The relation between these two kinds of fibers is of interest to the practical cotton breeder, and to the research worker, because of the correlation which exists between the quantity of the fuzz and the productivity of the variety. There are also important relations between the quantity and distribution of the fuzz and behavior of the lint in processing and manufacture.

The inheritance of fuzz pattern in upland cotton (*Gossypium hirsutum*) has been studied and reported by several investigators and some of these workers have pointed out certain phases of the relationship between lint and degree of seed fuzz cover in their material. The present work, however, has been set up to make a more detailed study than previously conducted of fuzz pattern and its bearing on or relationship to amount of lint. Since the upland species represents more than 99 per cent of the cotton crop of the United States the findings of this investigation have definite and extensive possibilities of practical application.

Materials and Methods

In providing desirable contrast in degree of fuzz cover and quantity of lint, two widely different upland stocks were chosen as parental material for the cross. These were the Hastings Upright and the No Lint varieties. Both stocks had been self-pollinated for six years and, therefore, were highly homozygous. The Hastings Upright variety has very abundant fuzz attached in a thick mat covering the entire surface of the seeds, while the No Lint variety has naked seeds and sparse lint.

For the purpose of evaluating the amount of fuzz cover or degree of nakedness, a set of seed cover standards or grades has been set up which ranges numerically from 1 to 20. These grades are shown in Figures 9 and 10. Grades 1 to 10 represent the degrees of true fuzziness, while Grades 11 to 20 show the stages of vanishing fuzz ranging from a vestigial tip brush to complete nakedness. The latter range, especially from 13 to 20, is largely characterized and differentiated by degree of ciliation or downiness of appearance caused by adhering broken-off basal lint segments. As the fuzz tip totally disappears from Grades 10 to 13, the amount of basal lint segments rapidly rises, being most abundant in Grade 13 and then in turn gradually tapers off to a state of complete absence in Grade 20. Grades 11 and 12 are not very commonly found in segregations of this kind and are thought of as transition stages between the fuzzy and naked-adherent classes.‡ No plants occurring in this work fall into these two grades. However, in some other studies carried on by the writer such grades have occasionally been seen. Grade 17 is also a transition grade between the F_2 naked-adherent and naked classes and does not occur in this material. Grade 20 is set up as an ideal state of fuzz and fiber absence and seldom occurs in nature. No such plants are reported in this work, but a few plants of this description have been seen in other segregates and have been

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†Resigned from Arkansas Station staff December 31, 1934. At present with the Division of Cotton and Other Fiber Crops and Diseases, Bureau of Plant Industry, U. S. Department of Agriculture, Washington, D. C.

‡Grades 1 to 10 make up the fuzzy class, Grades 13 to 16 the naked-adherent class, and Grades 18 and 19 the naked class.

observed as sports in cotton fields on one or two occasions.

Quantity of lint has been determined by the lint index method which is defined as the amount of lint from 100 seeds expressed in grams. This determination was made on each plant as were the seed grades.*

Progenies of the Hastings Upright and the No Lint plants used in the cross were grown the following year alongside the F_1 row for comparison. The parental strains were not continued further for this particular study, but F_2 and F_3 generation materials were produced in the two following years.

Results

In accordance with the seed cover standards shown in Figures 9 and 10, the seeds of the Hastings Upright parental plant and its twelve direct progenies were graded 3; the No Lint parental plant and its 243 direct progenies, 19; and the fifteen F_1 plants, 15. Lint index frequencies for these three groups are shown in Table 1 using a class interval of 0.25 grams. It is clearly shown in the last column of the table that the three populations are completely separated, but that the F_1 plants approach the high lint parental group much more closely than the other or low lint parental group. On the other hand, the F_1 seeds are more like the No Lint parental group in that the fuzz is absent. The means recorded below the frequency columns of the table also serve to point out the wide difference in lint production among the three populations, especially between the No Lint and the F_1 groups. The *t* values† at the base of the table confirm the validity of these relative differences.

The F_2 Generation

The F_2 generation includes 1,161 plants grown as nine separate progenies from the nine F_1 plants which were seeded for this purpose. Each of these progenies segregates into three general groups according to seed covering: the fuzzy, the naked-adherent, and the naked classes. Table II, reporting the F_2 plants for seed cover and lint index, indicates these three groupings for the total of the generation only. The separate segregations of the nine F_2 progenies, however, were tested separately by the chi-square method to determine agreement of observed seed cover classes with expected numbers required for a 1:2:1 ratio. These chi-square values range on Fisher's[2] probability scale from 0.90 to 0.10 except with one progeny including 93 plants whose value corresponds to a point outside of the 0.01 level. However, in the test for the entire F_2 group the observed 294 fuzzy, 593 naked-adherent, and 274 naked plants fit expected numbers satisfactorily, with a probability value of a little over 0.50.

The fuzzy or recovered parental fuzzy class breaks down into a range of fuzz patterns extending from that of the parent or Grade 3 to Grade 10, the latter being the hilum-tipped or lowest true fuzz grade. The heterozygous group described as the naked-adherent class, and, in general, the recapitulation of the F_1, spreads both ways into three grades (Grades 14, 15, and 16). The recovered parental naked class also varies and has some plants which possess more broken-off lint base segments than the parent type. Such plants are placed in Grade 18.

It will be seen in Table II that the lint indexes of the three general F_2 seed cover classes correspond to those of the respective parental and F_1 types. However, the average lint index (4.48) of the fuzzy class and the average lint index (3.31) of the naked-adherent class are somewhat lower respectively than those of the parental fuzzy (4.95) and of the F_1 (3.54) groups. Furthermore the

*The seed index (which is the weight of the same 100 seeds used in obtaining lint index) has been recorded also. From the weight of the unginned cotton used in determining the indexes, the lint percentage with respect to the seed cotton has been determined in addition. For the purpose of developing this subject here the seed index and lint percentage data are not essential, but they are filed for reference in case some reader wishes to inquire further into the results of these two variables.

†For computing "t" values see Fisher,[2] Snedecor,[4] and Livermore.[3]

average lint index (0.86) of the naked class is higher than the average lint index (0.48) of the parental naked group. Also, there is a greater frequency spread respectively among the three F_2 seed cover class populations in lint index as well as in seed pattern (already pointed out) than in the parental and F_1 plant arrays. The amount of overlapping between any two of the three classes for lint index is indicated by the total frequency in the last column in Table II. The means for the three classes are widely separated, but there is less difference between the fuzzy and naked-adherent classes than between the naked-adherent and naked classes. This was expected and simulates the parental and F_1 differences. The lint index frequency ranges and mean values of the seed grades provide comparison of lint level among these grades within the seed cover classes as well as among the three seed cover classes themselves. The *t* test was applied to the mean differences of lint index as among all the F_2 seed grade arrays and such deviations that showed significance are reported at the base of Table II. By comparing the mean values in this manner the validity or nonvalidity of differences was assayed.

Lint index is unaffected by fuzz patterns within the fuzzy class. Apparently so long as the hilum tip is present, lint level remains practically stationary. The lint index means of the three grades of the naked-adherent class, however, drop from Grade 14 to 15 and to 16, but the *t* values show significant differences between the last two only. The two grades in the naked class also are signficantly different for lint, Grade 18 being higher than Grade 19. Interclass grades, such as Grade 9 vs. Grade 14 and Grade 16 vs. Grade 18, as expected, indicate real differences in lint level. The three grades in the naked-adherent class and the two grades in the naked class, all classified on the basis of amount of broken-off or cut-off basal lint segments and, consequently, closely associated with lint populations, naturally would be expected to show lower lint index as the ciliation or downiness tends to subside.

The F_3 Generation

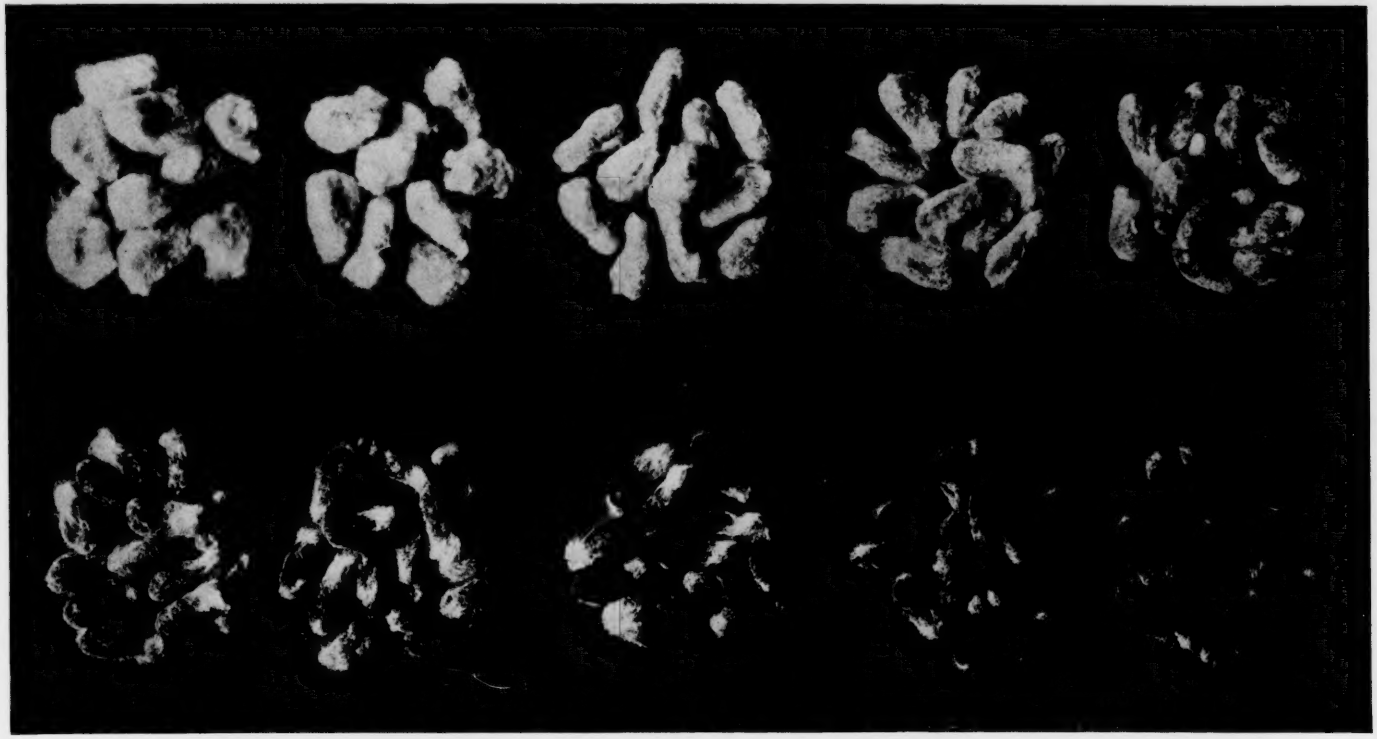
The F_3 generation plants are classified for fuzz pattern and lint index level in the same manner as the F_2 generation, and their data likewise stratified in Table III according to seed cover and lint index. The individual plant stocks for growing the F_3 generation were drawn from the F_2 populations more or less at random. Seventy-eight of these plants were grown from Grades 4 and 6 of the F_2 fuzzy class, 181 from Grades 14 and 15 of the F_2 naked-adherent class, and 39 from Grade 19 of the F_2 naked class. As the F_2 Grades 4 and 6 showed no differential influence in fuzz pattern and in lint index on their respective progenies, these two groups of F_2 offspring are combined into one group for presentation in Table III. Likewise the progenies of the two naked-adherent grades appeared to possess little difference and are classified together. Only one F_2 naked grade was used to represent the naked class in the F_3.

F_3 Progeny of F_2 Fuzzy Class

The 78 F_3 progenies from F_2 Grades 4 and 6 separate into Grades 2, 3, 4, 5, and 7, but 66 per cent of the group return to the original parental Grade 3. Only one plant is in Grade 2 and two in Grade 7. However, 18 plants occur in Grade 4. This tendency apparently indicates that a settling down to the parental type of seed fuzz begins to occur in the F_3. The lint index mean in Grade 3 and the lint index value of the one plant in Grade 2 are higher than in the other three grades, but the *t* values as calculated for paired differences among Grades 3, 4, 5, and 7 do not indicate significance except between Grades 3 and 4 where $t = 2.99$ (2.65 required for odds of 99:1). The results of this F_3 group are given at the left in Table III.

F_3 Progeny of the F_2 Naked Class

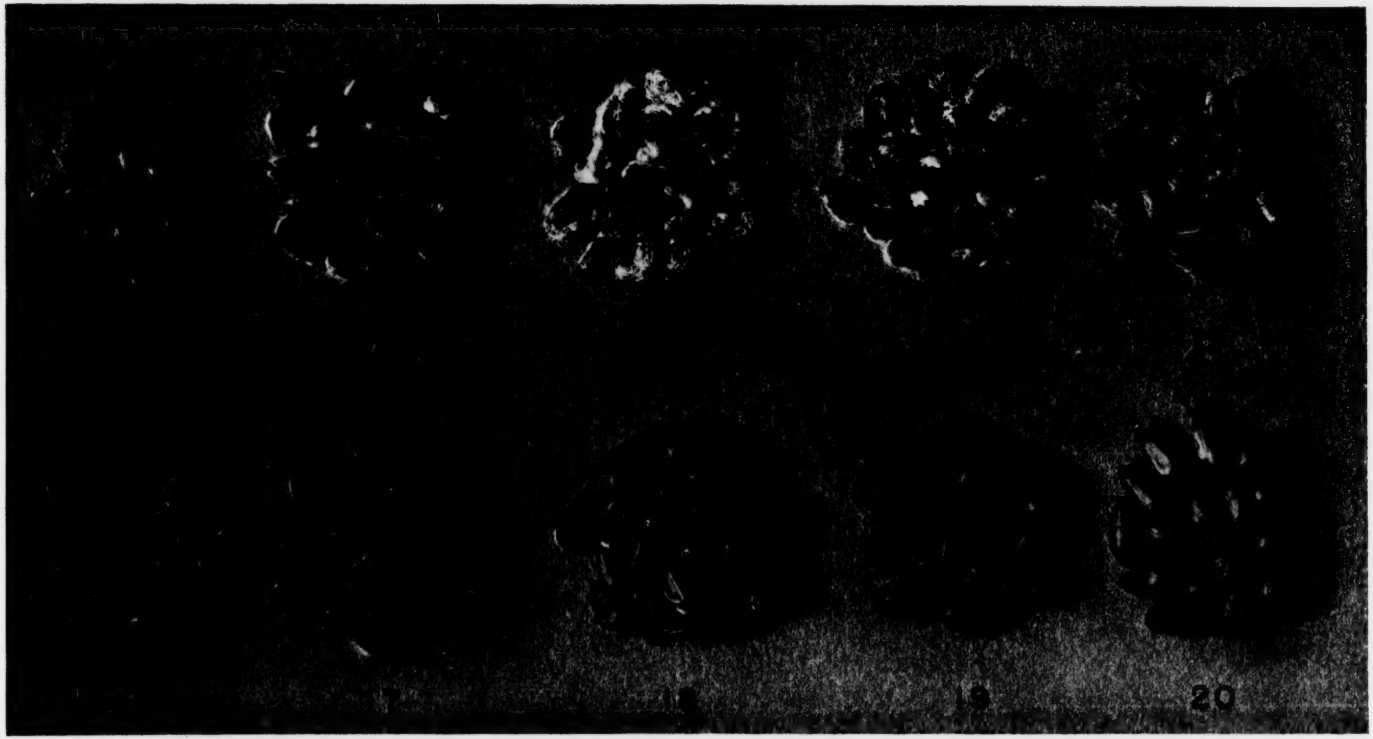
The 39 F_3 progenies from F_2 Grade 19 broke up into the two naked class grades, that is, Grades 18 and 19, with 14 plants in the former and 25 plants in the latter grade. The lint index levels in these two F_3 grades are about the same as with the two respective grades



GRADES OF SEED WITH FUZZ IN UPLAND COTTON

Figure 9

Twenty grades of extent of seed cover in Upland cotton have been established for the purpose of this study, and the first ten are shown in this Figure. In these ten grades, representing the fuzzy class, there is a decreasing distribution of fuzz over the entire surface of the seed coat, but with a heavy tuft remaining on the hilum tip. The other ten grades are shown in Figure 10.



GRADES OF SEED WITHOUT FUZZ IN UPLAND COTTON

Figure 10

Grades 11 and 12 are transitional stages; grades 13 to 16 constitute the naked-adherent class; grade 17 another transition stage; and grades 18 and 19 the naked class. The three transition grades were included in this series to make it complete, but were not encountered in this study. Completely naked seeds, as represented by grade 20, are very rarely found in nature.

in the F_2, but a larger proportion of the plants occur in Grade 18 of the F_3 generation than in this grade of the F_2. The *t* value for difference between Grades 18 and 19 of the F_3 is 4.99 (2.72 required for odds of 99:1). See Table III, at right.

F_3 Progeny of the F_2 Naked-Adherent Class

The behavior of the F_3 segregation from the F_2 naked-adherent class is similar to the F_2 segregation itself, except that a lesser number of fuzzy grades occur in the fuzzy class and, on the other hand, one more grade in the naked-adherent class. The lint index levels of the three respective seed cover classes in this section of the F_3 and in the F_2 generation correspond rather closely. The F_3 fuzzy class mean of this section is 4.26 and the F_2 fuzzy class mean, 4.48; the F_3 naked-adherent class mean is 2.97 and the F_2 naked-adherent class mean, 3.31; the F_3 naked class mean of this section is 0.74 and the F_2 naked class mean, 0.86. The lint index frequency of the 181 F_3 plants coming from the F_2 naked-adherent class indicates about the same degree of overlapping between classes as occurs in the F_2.

From the naked-adherent F_2 class, ten plants were seeded and the resulting F_3 progenies were tested by chi-square for fit to a 1:2:1 ratio. In this test the *P* values ranged from 1.00 or a perfect fit to a little above 0.05 with the exception of one, which has a *P* value between 0.05 and 0.02, but nearer to the latter level. The distribution of the total of the 181 plants among the three seed cover classes corresponds to expected numbers closely as is expected by the probability value of approximately 0.80.

The lint index levels among the three fuzzy grades of this group show no significant difference, while the difference between Grades 18 and 19 of the naked class as expected indicate a real difference, *t* being 5.66 (2.70 required for odds of 99:1). Among the four grades of the naked-adherent class no significant lint index differences occur between Grades 13 and 14 and between 15 and 16, but between 14 and 15 a definite drop occurs, the *t* value for this difference being 5.59 (2.64 required for odds of 99:1).

The lint levels in none of the corresponding grades in the two fuzzy groups nor in the two naked groups of the F_3 differ significantly except in Grade 4, one group coming from the progeny of the fuzzy F_2 class and the other group coming from the currently segregated F_3 fuzzy class, and in Grade 19, one group coming from the progeny of the F_2 naked class and the other coming from the currently segregated F_3 naked class. The *t* value for the lint index difference in the two Grade 4 groups is 4.66 (2.72 required for odds of 99:1); and the lint index difference in the two Grade 19

Table I. Seed Grade and Lint Index of Parental Strains and F_1.

Lint Index	Parental Line: Hastings Upright Covered Seed Grade 3	F_1 Generation: Naked-adherent Seed Grade 15	Parental Line: No Lint Naked Seed Grade 19	Total Plants
5.50	1			1
5.25	2			2
5.00	4			4
4.75	4			4
4.50	1			1
4.25				0
4.00		3		3
3.75		2		2
3.50		6		6
3.25		2		2
3.00		2		2
2.75				0
2.50				0
2.25				0
2.00				0
1.75				0
1.50				0
1.25				0
1.00			3	3
0.75			56	56
0.50			99	99
0.25			85	85
N	12	15	243	270
Mx	4.95	3.54	0.48	
SEs	0.304	0.275	0.174	
SEm	0.092	0.073	0.011	

Mean Differences:
Hastings Upright and No Lint, "t" value 83.10 (2.59 required for odds of 99:1).
No Lint and F_1, "t" value 63.40 (2.59 required for odds of 99:1).
Hastings Upright and F_1, "t" value 12.64 (2.79 required for odds of 99:1).

groups is 3.95 (2.68 required for odds of 99:1). However, since the number of individuals in most of the F_3 grades is small and possibly in all cases not constituting fair samples, it should not be definitely taken here that the fuzzy grades among themselves differ in lint production nor that the same grades in the naked class, one arising from the F_2 segregation and the other arising from the F_3 segregation, have lint indexes at different levels.

Discussion

In view of the behavior of seed fuzz patterns exhibited in this work and their apparent relation to lint level, further study of the heritable relationship of these two traits would be of interest. As previously mentioned, several workers

Table II. Seed Grade and Lint Index of F_2 Generation.

Lint Index	Fuzzy Grades 3	4	5	6	7	8	9	10	Total	Naked-Adherent Grades 14	15	16	Total	Naked Grades 18	19	Total	Total F_2 Plants
6.00		2		1					3								3
5.75	1	0		0					1								1
5.50	1	1	4	0		1			7								17
5.25	5	8	1	0		0			14								14
5.00	5	9	8	5	4	1			32	1			1				33
4.75	17	15	13	5	2	0		1	53	1	2		3				56
4.50	14	20	15	5	3	1	2		60	3	2		5				65
4.25	14	19	10	5	4	3	1		56	10	6		16				72
4.00	7	15	12	5	2	1	1		43	10	35		45				88
3.75	3	8	3	3		0			17	23	52	3	78				95
3.50	2	2	2			1			7	36	64	6	106				113
3.25		1							1	57	84	3	144				145
3.00										33	65	6	104				104
2.75										14	34	4	52				52
2.50										5	12	5	22				22
2.25										2	6	1	9	2		2	11
2.00											1	1	2	2	1	3	5
1.75											1	1	2	2	2	4	6
1.50											0	2	2	5	11	16	18
1.25											1	1	2	9	33	42	44
1.00														6	48	54	54
0.75														3	61	64	64
0.50															68	68	68
0.25															21	21	21
N	69	100	68	29	13	8	4	1	294	195	365	33	593	29	245	274	1161
Mx	4.52	4.47	4.49	4.45	4.50	4.44	4.24	4.74	4.48	3.38	3.32	2.87	3.31	1.37	0.80	0.86	3.03
SEx	0.446:	0.518:	0.664:	0.500:	0.333:	0.640:	0.271:			0.450:	0.461:	0.678:		0.401:	0.341:		
SEm	0.054:	0.052:	0.057:	0.094:	0.089:	0.242:	0.157:			0.032:	0.024:	0.120:		0.076:	0.022:		

Chi-square test, fuzzy 294, naked-adherent 593, naked 274 ---------- P = 0.50 +

Mean Differences:

Grade 9 and Grade 14, "t" value 3.80 (2.60 required for odds of 99:1).
" 16 " " 18, "t" " 10.42 (2.66 " " " " ").
" 15 " " 16, "t" " 5.13 (2.59 " " " " ").
" 18 " " 19, "t" " 8.35 (2.59 " " " " ").

Table III. Seed Grade and Lint Index of F_3 Generation.

Lint Index	Progenies of F_2 Covered (F_2 Grades 4 & 6): F_3 Grades 2	3	4	5	7	Total	Progenies of F_2 Fuzzy (F_2 Grades 3, 4, 5, 6, 7, 8, 9, 10): F_3 Grades 3	4	5	Total	Progenies of F_2 Naked-Adherent (F_2 Grades 14 & 15): F_3 Grades 13	14	15	16	Total	Progenies of F_2 Naked (F_2 Grade 19): F_3 Grades 18	19	Total	Total F_3 Plants
5.50		2				2			1	1							1		1	5
5.25		2				2			0	0							0		0	2
5.00		3				3		2	0	2							2		2	5
4.75	1	6				7	1	3	0	4							4		4	11
4.50		4	1			5	4	2	3	9		1			1		10		10	15
4.25		6	1	2		9	2	5	1	8	2	2			4		12		12	21
4.00		6	1	0		7	7	4	2	13	0	1			1		14		14	21
3.75		10	7	1		18	2	3		5	4	1	2		7		12		12	30
3.50		10	6	2	2	20		1		1	1	3	0	1	5		6		6	26
3.25		3	1			4					1	3	8	1	13		13		13	17
3.00			1			1					0	5	14	1	18		18		18	19
2.75											1	0	19	1	21		21		21	21
2.50											1	2	11	0	14		14		14	14
2.25													5	0	5		5		5	5
2.00													4	0	4		4	2	6	6
1.75														1	1	1	2	3	1	4	6
1.50														0	0	2	1	3	2	5	5
1.25														1	1	7	1	8	3	11	14
1.00																2	3	5	2	4	6	11
0.75																1	5	6	2	11	13	19
0.50																0	12	12		6	6	18
0.25																0	6	6				6
0.00																1	2	3				3
N	1	52	18	5	2	78	16	20	7	43	10	16	63	6	95	14	29	43	181	14	25	39	298
Mx	4.83	4.12	3.67	3.82	3.52	3.99	4.19	4.45	4.43	4.26	3.55	3.45	2.78	2.64	2.97	1.16	0.53	0.74	2.74	1.40	0.85	1.05	
SEx		0.60:	0.36:	0.39:	0.99:		0.30:	0.43:	0.49:		0.58:	0.61:	0.37:	0.88:		0.44:	0.30:		0.39:	0.28:		
SEm		0.08:	0.08:	0.17:	0.99:		0.07:	0.09:	0.20:		0.19:	0.15:	0.04:	0.29:		0.11:	0.05:		0.10:	0.05:		

Chi-square test. Segregation of F_2 heterozygous or naked-adherent class, fuzzy 43, naked-adherent 95, naked 43 -------- P = 0.80 -

Mean Differences:

Grade 5 and Grade 13 (from naked-adherent F_2 class), "t" value 3.32 (2.95 required for odds of 99:1).
" 16 " " 18 " " " " " " "t" " 5.20 (2.88 " " " " ").
" 3 " " 4 (from fuzzy F_2 class), "t" " 2.99 (2.65 " " " " ").
" 14 " " 14 (" naked " "), "t" " 4.99 (2.72 " " " " ").
" 18 " " 19 (in naked F_3 class), "t" " 5.66 (2.70 " " " " ").
" 14 " " 15 (in naked-adherent F_3 class), "t" " 5.59 (2.64 " " " " ").
Grade 4 (from fuzzy F_2 class) and Grade 4 (in fuzzy F_3 class), "t" value 4.66 (2.72 required for odds of 99:1).
" 19 (" naked " ") " " 19 (" naked " "), "t" " 3.95 (2.68 " " " " ").

have made some study of such or similar patterns and in some cases have shown attendant lint production evaluations.

Thadani[5] reported some results of intercrosses among plants representing different degrees of fuzz covering or fuzz patterns in upland cotton. He referred to the different quantities of fuzz as "woolly," "felted," and "scanty." These classes seem to approximate respectively Grades 3. 5, and 7 as indicated in Figure 9. In the F_1 of Thadani's crosses, felted was dominant to woolly and scanty to woolly indicating that less fuzz is dominant to more fuzz. However, he did not determine the relationship between scanty and felted. Crosses of the naked seed and sparse lint type with felted and with scanty in Thadani's work showed naked seed to have the same relationship to these patterns as to fully covered in the F_1.

Winters et al[6] isolated a strain having a naked seed body and a hilum fuzz tip similar to Grade 10 in this work. Plants with the fuzzy tip seeds when crossed with plants having seeds fully covered with fuzz produced fuzzy tip seeds in the F_1 generation; and in the F_2 and F_3 generations breeding results indicated a 3:1 ratio of fuzzy tip to fuzzy. However, when the fuzzy tip was crossed with fuzzless or fully naked, a dihybrid 12:3:1 ratio of naked, fuzzy tip and fuzzy was obtained in the F_2. In the next generation this fuzz pattern ratio was verified and from the range or degree of lint sparseness among the plants of the segregated homozygous naked class, two groups, one ranging from a lint percentage of 4 to 8 and the other from a lint percentage of 16 to 20, were isolated.

Carver[1] also carried out a similar study in which he obtained a 3 to 1 ratio for tipped and covered and a 12:3:1 ratio of naked, fuzzy tip, and fuzzy when naked and fuzzy tip parents were crossed.

It appears here that less fuzz is dominant to more fuzz and that naked seed is dominant to the whole fuzz pattern series. The results in the reviewed material and in the reported work of this paper indicate that varieties having one or more stages of sparse fuzz can be stabilized and that lint production of such types would not be reduced as a result of this character association.

Summary

Seed pattern standards were set up and numbered as grades from 1 to 20. These grades are defined in the text, and are illustrated in Figures 9 and 10. Grades 1 to 10 represent the recovered fuzzy class, Grades 13 to 16 the heterozygous or naked-adherent class, and Grades 18 and 19 the naked class. These classes in the F_2 and in the F_3 groups derived from the heterozygous F_2 class occur in the 1:2:1 ratio. The fuzzy and the naked as classes breed true. The naked-adherent class characterized by the attached lint base stubs or segments breaks up indefinitely.

The lint value is measured as lint index. High lint is associated with fuzz presence and the sparse lint with the naked seeds. Correlation of these fiber-lint relationships seems complete with the exception of some minor effects of modifiers.

It is pointed out in the discussion of this and other work reviewed that varieties of cotton having a sparse fuzz and high lint combination may be bred for commercial use.

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